Multimodular Complex Riding On Air Cushion Used For Internal Fitting and Finishing Work

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ABSTRACT: Self-Propelled manipulation system which is a mobile robot uses for its movement a chassis, a device on aerostatics supports. The catch of the manipulation system takes its positions at the point of support on the indoors floor and clutches with it. By means of its drives the manipulation system moves chassis into its initial position for fulfilling technological operations. After this, chassis is stabilized in the initial position while the manipulation system is transmitted into its operating position The use of pantograph in the kinematic scheme of the manipulation system enables to mount the drives on the chassis directly as well considerably to extend the zone of service from one point of support. When using the mobile robot indoors on the chassis having a load weight up one ton the dimensions of operating zone are up to four meters high with indoors area up to thousand square meters.

KEYWORDS: manipulation system, mobile robots, aerostatics supports, construction, kinematics.

1. INTRODUCTION

Some process like those involved in fitting, finishing and auxiliary work in housing and industrial construction are both labour intensive and difficult to automate, among them numerous hauling operations concerned with moving materials and tools over a construction site. Yet, they need to be calculated against time since contemporary fitting and finishing operations demand that motional functions be performed accurately and effectively.

A robot-based area designed to provide for accurate manipulation of diverse equipment and for extensive handling schemes could significantly reduce the labour input and hence, increase profitability of operations. Multi-modular structure of major function subsystem in the area and a hierarchical control and intelligent system could do the job, the structural elements being a hovercraft (HC), a multifunctional manipulation system (MS) and a navigation system ensuring adequate accuracy of all handling operations all over the construction site.

2. THEORY AND EXPERIMENT

Processes taking place in the automated construction site impose certain requirements on the robot motive capabilities. These requirements can be met by including in the structure of the manipulation system of an adequate number of axes. In accordance with the classification accepted in robotics, there are the following groups of joint motions:

- global motion – within the entire area of the construction site;
- regional motion – displacement of a gripping device within the workspace determined by the length of the manipulator chain links;
- mall displacements of manipulator end link in a limited area of workspace.

In accordance with this classification, the overall structure of manipulator can be broken down into kinematic sections which perform various functions.

Robot must be mobile, i.e. able to move around the worksite. Global motion are to be generated by a vehicle riding on an air cushion and in addition, provide for the vehicle orientation with respect to the coordinates set by the benchmarks fixed on the territory of the worksite.

The above considerations allow us to design a conceptional manipulation system of an automatic programmable mobile robot to use it on a 1,000

m^2 worksite up to 4 m high. When conceiving a MS structure, one
should strive to keep the number of axes minimal but sufficient (W=6) and to choose cylindrical coordinates as ensuring a simpler way of motion programming. The conceptional MS model and its kinematics are shown in fig.1.

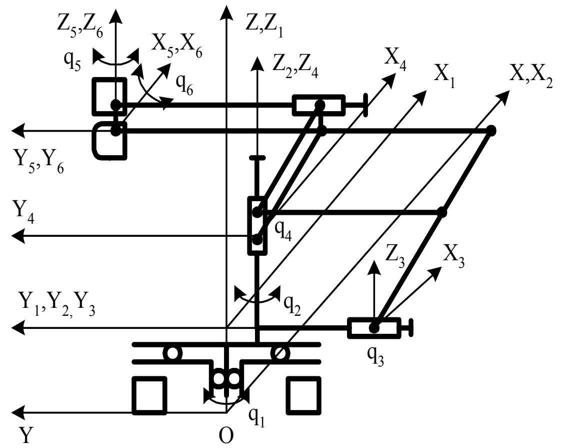

Figure 1. Kinematic structure of robot manipulation system

The axes serve the following purposes: q_1 - replacement of the manipulator arm from transport position to a working position; q_2 - arm rotation to get a working instrument to more along the longitudinal axis of a benchmark; q_3, q_4 - coordinate displacement of working instrument along vertical and lateral axes of benchmark; q_5,q_6 - hand rotation ensuring that the axes of the working instrument is perpendicular to the surface to be worked.
Linear translation of working instrument in MS can be performed by a pantograph mechanism, which can ensure linear dependence between coordinate hand displacements and internal coordinates q_3 and q_4 by means of slow speed drivers fixed at the base of manipulator. Let us look at the pantograph mechanism shown in fig.2.
The design of this manipulation system, when mounted on a hovercraft, allows travel relative to global generalized coordinates. In this case the structure will be rigidly attached at point H to the benchmarks on the area, while by means of MS and HC drivers it can move over the entire area of the construction site.

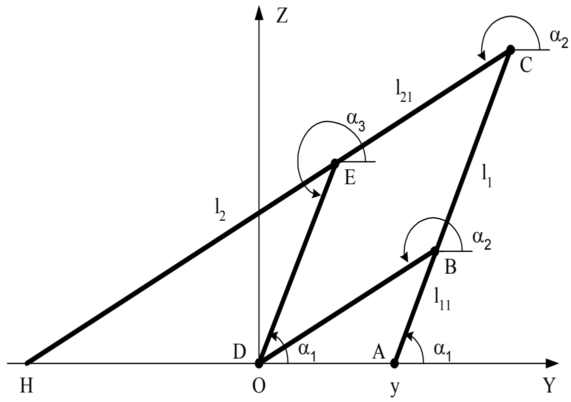

Figure 2. Pantograph mechanism

After MS is installed in a predetermined position, MS is brought into working position to perform fitting and finishing operations.

This mechanism consists of three loops OABDO, OACEDO and OACHO. In a complex form, the loop closing equations can be written as

$$y + l_{11} \cdot e^{i\alpha_1} + l_{21} \cdot e^{i\alpha_2} - i \cdot z = 0;$$

$$y + l_1 \cdot e^{i\alpha_1} + l_{21} \cdot e^{i\alpha_2} + (l_1 - l_{11}) \cdot e^{i\alpha_3} - i \cdot z = 0;$$

$$y + l_1 \cdot e^{i\alpha_1} + l_2 \cdot e^{i\alpha_2} - \boldsymbol{H} = 0, \qquad (1)$$

where y and z are displacements generated by independent motors along axes OX and OZ respectively. Real parts of equations (1) can be written as

$$y + l_{11} \cdot \cos\alpha_1 + l_{21} \cdot \cos\alpha_2 = 0;$$

$$y + l_1 \cdot \cos\alpha_1 + l_2 \cdot \cos\alpha_2 - H_y = 0, \qquad (2)$$

imaginary parts can be written as

$$l_{11} \cdot \sin\alpha_1 + l_{21} \cdot \sin\alpha_2 - z = 0;$$

$$l_1 \cdot \sin\alpha_1 + l_2 \cdot \sin\alpha_2 - H_z = 0, \qquad (3)$$

where H_y and H_z are orthogonal components describing displacements of the wrist.
Let us introduce link length ratios k_1, and k_2 which we shall call amplification factor

$$k_1 = \frac{l_1}{l_{11}} = \frac{l_2}{l_{21}}; \qquad (4)$$

$$k_2 = \frac{l_2}{l_1} = \frac{l_{21}}{l_{11}}. \qquad (5)$$

Amplification factor k_1 is a ratio of corresponding sides of similar triangles ADB and AHC. The mechanism will evidently be a pantograph if quadrangle BCED is a parallelogram and points A,B and H are in line.
The relation between k_1 and k_2 can be defined from the relationship:

$$\frac{DB}{BC} = \frac{l_{21}}{l_1 - l_{11}} = \frac{k_2}{k_1 - 1}. \qquad (6)$$

After introducing amplification factor k_1 into equations (2) and (3) a little manipulation yields:

$$H_y = (1 - k_1) \cdot y ;$$
$$H_z = k_1 \cdot z . \qquad (7)$$

Time differentiation of equation(7) yields relationships for speeds and accelerations:

$$H'_y = (1 - k_1) \cdot y' ; \qquad (8)$$
$$H'_z = k_1 \cdot z' ;$$

$$H''_y = (1 - k_1) \cdot y'' ; \qquad (9)$$
$$H''_z = k_1 \cdot z'' .$$

Pantograph mechanism used in manipulator appears to produce linear dependencies between input and output displacements, speeds and accelerations along each coordinate. In addition, this mechanism can be considered as a linear displacement amplifier with two amplification factors: $(1-k_1)$ for y-axis and k_1 for z-axis. The pantograph mechanism is based on a parallelogram. The ends of its four links are connected by kinematic turning pair in such a way that the pivot axes are perpendicular to the motion plane. This mechanism used for motion transmission permits higher rigidity of MS if relationships of mobile link lengths of the pantograph mechanism are chosen correctly. Like the links of the quadrangle, the other manipulator links experience tensile – compressive load and hence, are bend resistant, which is linearly depent on the mass-to-length ratio. This ratio can be significantly reduced by employing an off-loaded' MS with the drives brought out to the base of the manipulator. All above shows that pantograph mechanism can successfully be used when dealing with fitting and finishing operations.
The systems of robot manipulation, information-processing and control used in fitting and finishing operations in building and industrial construction (fig.3) include:

1. Vertical motion actuator; 2. Horizontal motion actuator; 3. Vertical position pickup; 4. Horizontal position pickup; 5. Vertical displacement pickup; 6. Horizontal displacement pickup; 7. Limit switch of vertical motion; 8. Limit switch of horizontal motion; 9,10 Screw-and-nut gearing; 11. manipulator links: width - pulse modulation converter; level matching device; interface; control computer; hovercraft.

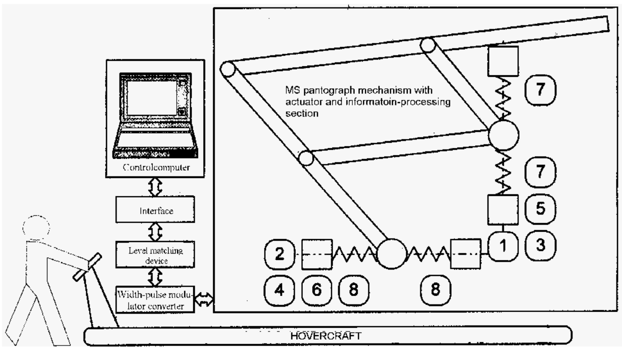

Figure 3. Functional diagram of robot control system

D.C. separately exited motor can be employed as a power generating unit of the manipulation system (1,2). Angular velocity of the motor is reduced by means of a reduction gear, and rotary motion is converted into transnational motion with required speed by means of screw-and-nut gearing (9,10). Control over the path-following motion is performed using optoelectronic vertical and horizontal positioning transducers (3,4). Developed using from a photon-coupled pair. "light-emitting diode–photodiode and disk-slit diaphragm mounted on the input shaft of the reduction gear. Control over the direction of joint motion is performed using analogue permanent magnet-field tachometers(5,6) with output tension of positive or negative polarity, depending on the rotational direction. The shafts of tachometers and motors are connected through belt transmission. Limit switches (7,8) are used as end-position pickups which also perform as switch-off protection devices.
MS actuators can be controlled by pulse-duration modulation of computer signal.

Global travel is affected by a hovercraft. A hovercraft has several advantages over conventional vehicles employed at construction sites. They are:

1. low tractive resistance; material handling by a hovercraft requires much less tractive force than by wheel or clawler-belt transport;
2. better maneuverability in a horizontal plane; a hovercraft provides motion and turn in any direction as well as rotation about its axis.
3. Better load-carrying capacity;
4. low pressure brought to bear on support surface, which leads to reduced floor wear and hence, its increased durability;
5. simplicity of design and relatively low manufacturing cost, which allows capital costs to be cut down.
6. low cost of service, because hovercraft operation does not require specially trained personnel.

3. STATEMENT

The purpose of this development is to increase efficiency and safety of fitting and finishing operations on the construction.

To achieve this goal, one has to approach the following problems:

- to identify key requirements and principles of robotization of fitting and finishing processes;
- to conceive a model of the MS, determine its parameters and study its kinematics characteristics;
- to develop the algorithms of control of robot motions and principles of building an adequate navigation system;
- to study drive dynamics of major axes and adaptability of axes motion under changing mass-inertia characteristics of robot manipulation system;
- to materialize model algorithms and produce recommendations on their practical application.

4. REFERENCES

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